The footprint of organic farms

some ecological indicators to evaluate it

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Abstract

Agro-ecological indicators are a tool which provides an agile evaluation of the ecological footprint of a farm. This paper analyses the preliminary results of a survey in which 7 agro-ecological indicators were calculated for 81 organic farms in the region of Lombardy in the northern part of Italy.

The indicators chosen (all indicators of State) are: hedges and rows, energy input, energy output, energy output/input ratio, N balance, P2O5 balance, works unit per hectare.

The preliminary results suggest that these indicators allow to discriminate between different farms on the basis of the productive orientation (cropping classes). In perspective, the use of indicators may enable farmers to improve the management of their farm, evaluating the ecological footprint in order to reduce it gradually

Introduction

As recently stated by IFOAM, with the term "organic farming" we can understand the management strategy which aims to achieve three sets of goals:

a) to exploit the natural levers of production, in order to preserve the agro-ecosystem and to maintain the integrity of its functional complexity for the future generations;

b) to provide wholesome products in adequate quantities to satisfy the needs of society;

c) to ensure stable and satisfactory incomes to the various actors in the whole food chain (production-processing-consumption), according to the paradigm planet / people / profit, which summarizes the elements of this conception.

To achieve these purposes we must develop, both in the surveys and in practical application, a holistic approach that considers the complexity of the agroecological system.

The context of organic farming has always been characterized by issues relating to the health of the products and the environment, which are of paramount importance. Concurrently, we need to elaborate effective methods and tools for an assessment of enterprises, especially with regard to their ecological footprint. In particular, the point is how to assess not only the quality of the products, but also the contribution to the safeguard of the environment, especially on farm level. Comparing to the general problem of agro-environmental assessment of agricultural systems, some specific needs arise if we consider the sustainable issues, such as:

i) developing tools that enable the transfer of knowledge from research to the farmers, and to the public management officials

ii) summarize and systematize the knowledge for different production systems (e.g. animal husbandry, horticulture) please do not call a farm "industry"! that is something we try hard to avoid in organic farming and different environments

iii) minimize the effort required for data acquisition

iv) simplify the evaluation, to make them the most transparent and robust and therefore can hardly debatable.

Due to the aim of organic agriculture to preserve the agroecosystems, it is particularly required for organic farms to utilize(the researchers should develop the tools) tools that enable a systematic and efficient use of available scientific knowledge, transferred to the productive context e.g. by "check lists" consisting of quantitative agro-ecological indicators.

The EU has recently defined a set of agro-ecological indicators (AEI). The European Environmental Agency (EEA) proposes to classify The AEIs according to the scheme DPSIR (Driving forces, Pressure, State, Impact, Response). During the conceptual definition of AEIs it is necessary to specify whether you should use:

- An indicator of *Driving forces*, which can be useful in quantifying human activities and behaviors related to individual and social needs, economic and productive processes and consumption which causes environmental pressures;
- An indicator of *Pressure*, which can be used to quantify the result of the presence of driving forces in the affected area;
- An indicator of *State*, which quantifies the environmental quality or features to be protected and preserved endangered by pressures;
- An indicator of *Impact*, characterizing the state of the significant changes that appear as alterations in the ecosystems;
- An indicator of *Response*, which can be able to quantify the changes occurring as a result of actions addressed to face the impacts. Not necessarily the government that takes action here! Farmers may act as well!

The survey INDIA (Agro-ecological indicators for organic agriculture)

The survey INDIA was carried out by the Department of Food Crops (DiProVe) of the Faculty of Agriculture – State University of Milan, and financed by the Agriculture Department of the Lombardy Region. Stefano Bocchi was the scientific supervisor; Luca Bechini and Roberto Spigarolo carried out the survey.

The purpose of this survey was to identify some indicators of crop production in order to be able to compare different farms regarding their sustainability level and to provide farmers with a simple tool for assessment of their management.

The agro-ecological indicators can be used to calculate the footprint of the organic farms and to make a comparison between them and with other types of farms (conventional and/or sustainable).

The method of calculation of the indicators used corresponds to that developed for a similar research "Application of Agro-Ecological and Economic Indicators in Northern Italy" carried out by DiProVe on conventional farms of the "Sud Milano Agricultural Park" – an area located south of Milan.

Some factors, like chemical pesticides or chemical fertilizers, were not considered in this survey because they are not applicable in the context of organic farming.

All the survey was made at "farm level" and consider only the crop production. In a second part of the survey, that will be carried out next year, also the livestock indicators will be considered and a comparison with conventional and/or sustainable farms will be developed.

A group of researchers collected the data visiting all the farms, using a checklist. All the collection of data was carried out in the first 8 months of 2008, and refers to the production of an entire year (2007). Then, in the last months of 2008, all data collected were submitted in the devoted software program. The results were presented and discussed in a seminar organized by Lombardy region in march 2009.

Materials and methods

1. The sample selection

The sample for the survey was selected from the official database of organic farms in the region of Lombardy, in the northern part of Italy, subjecting the initial scope to a double selective filter:

- only entirely organic farms were selected. Partially conventional farms have been excluded: that ruled out the possibility of considering "parallel crops";
- only those farms that had completed the conversion period were selected.

This allowed us to circumscribe the scope and to provide uniform data analysis.

Altogether, 81 farms were selected. This number of farms represents more than 20% of all the entirely organic farms that had completed the conversion period in Lombardy.

This sample was chosen according to a matrix that interlaces two selection criteria:

- the territorial representation: it was considered the "territorial weight" in terms of number of farms present in the various provinces;
- the representativeness of ordering crops: it was considered the number of organic farms by type of cultivation system according to the official national classification.

The survey is based on data on crops grown in 2007.

The farms were classified into cropping system (Fig 1), farm size (Fig. 2) and land type (plain, hills or mountains, Fig. 3)

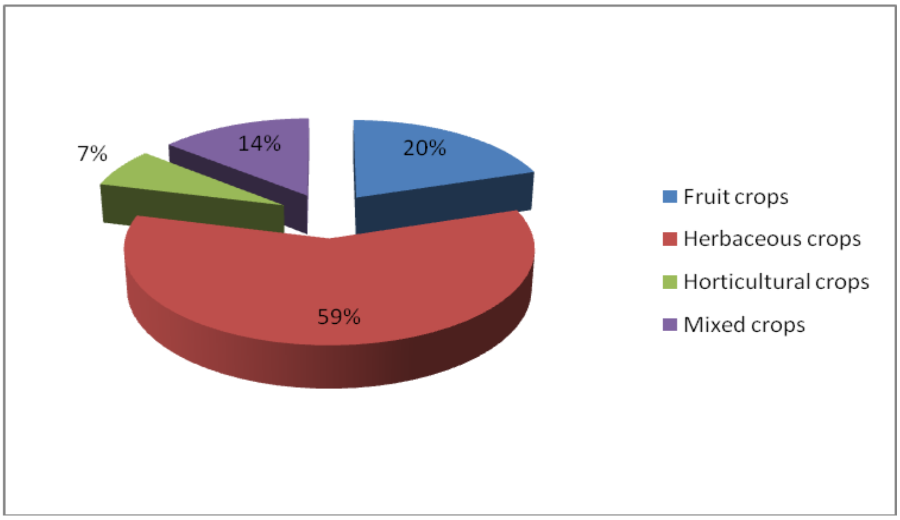

Fig. 1. Share of the farms (n =81) in various cropping systems

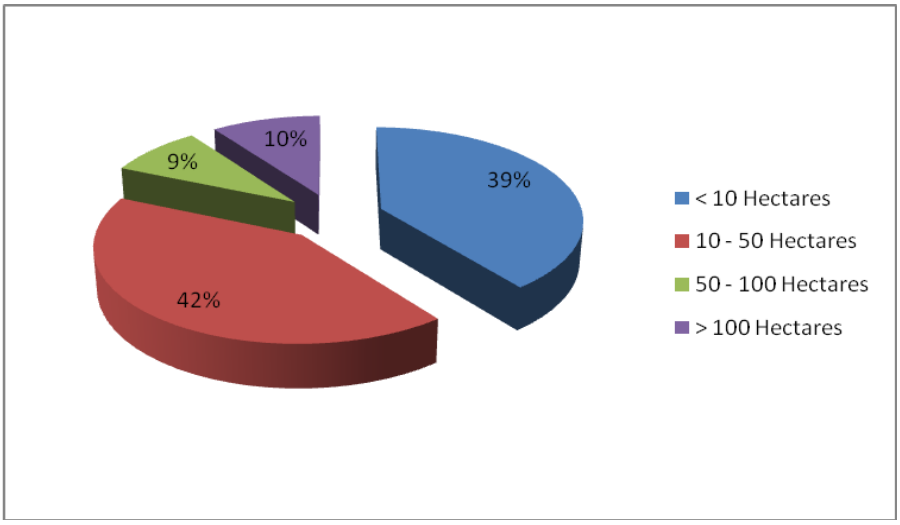

Fig. 2. Share of the farms (n = 81) in various groups of acreage

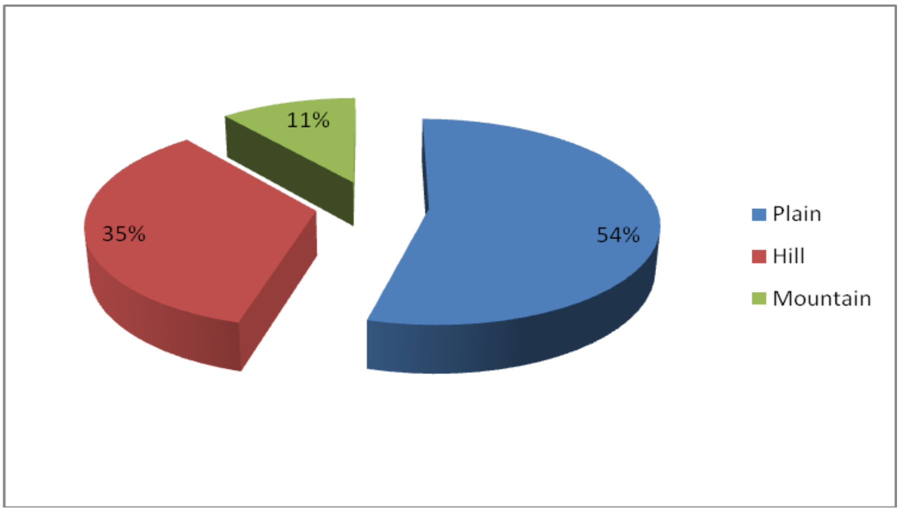

Fig. 3. Share of the farms (n= 81) in different land types

2. The agro-ecological indicators used

Altogether, seven agro-ecological indicators were considered in this survey (a-g). In addition to energy input and output, N and P balance the amount of hedges and total workload were assessed. The first six indicators (a-f) were calculated also in the previous survey on conventional farms. Furthermore, some data are available on the workers employed in different farms. So, in the second part of the survey, a comparison with conventional and/or sustainable farms will be carried out.

All these are **Indicators of State**.

Below the method of calculation of each of them is highlighted.

For energy indicators, the specific energy equivalent (SEQ) of various factors included was used to calculate the energy input or output. The SEQ is the amount of energy stored or embedded in a factor per unit of volume, or per unit of mass, depending on the context, and is expressed in MJ * UM^{-1}. **UM = Unit of Measurement**

a. Hedges and Rows

were measured as meters of hedges and rows / ha of ASU = Agricultural Surface Used. It excludes the unproductive surface, as buildings, ditches.

b. Energy input

was measured as the sum of:

- **Machining:** input fuel consumption (l) * SEQ + lubricants (kg) * SEQ
- **Phytosanitary treatments**: pesticides used (kg) * SEQ - *only organic pesticides were considered*
- **Mineral fertilizer**: Mineral fertilizers used (kg) * SEQ (default values: kg N contained in 1 kg of fertilizer) – *not considered*
- **Organic Fertilizer:** Organic Fertilizer used (kg) * SEQ (default values: kg N contained in 1 kg of fertilizer / 2)
- **Energy embedded in machinery** (MJ * l^{-1} fuel consumed
- **Other materials**: quantity used (UM) * SEQ

N.B.: energy embedded in every material has been considered, according to the values of Table 1

Table 1. Energy embedded in the productive factors

Materials	UM	Energy embedded (MJ * UM^{-1})	Source
Surface irrigation	m^3	0,045	estimated
Sprinkler system irrig.	m^3	0,346	Ribaudo, 2000
Electricity	kWh	3,6	calculated
Diesel fuel	l	36,4	Patzek, 2004
Lubricants	kg	83,7	Dalgaard et al., 2000
Energy embedded in machinery	MJ/l of diesel consumed	12	Dalgaard et al., 2000
Harvest boxes (wood)	kg	2,5	estimated

Harvest boxes (plastic)	kg	125,6	estimated
PE for mulching	kg	125,6	estimated
Galvanized iron wire	kg	63	estimated
Chemical herbicides	kg	288	Biermann, 1999
Chemical fungicides	kg	196	Biermann, 1999
Chemical insecticides	kg	237	Biermann, 1999
Organic fungicides	kg	108	estimated
Organic insecticides	kg	50	estimated
String	kg	10	estimated
Plastic strings	kg	125,6	estimated
Mineral NH_4 fertilizers	kg FU (Fertilizer Unit)	39	Kongshaug, 1998
Mineral ureic fertilizers	kg FU (Fertilizer Unit)	48	Kongshaug, 1998
Mineral NO_3 fertilizers	kg FU (Fertilizer Unit)	32	Kongshaug, 1998
Mineral phosphatic fertilizers	kg FU (Fertilizer Unit)	4	Kongshaug, 1998
Mineral potassium fertilizers	kg FU (Fertilizer Unit)	5	Kongshaug, 1998
Vineyard stakes (wood)	kg	2,5	estimated
Seeds of winter cereals	kg	31,4	estimated
Seeds of corn	number of seeds * 1.000	20,376	estimated
Seeds of rice	kg	31,4	estimated
Seeds of forage grasses	kg	31,4	estimated
Seeds of pulses (soia, beans)	kg	40,4	estimated

N.B.: the factors highlighted in yellow were not considered in this survey

c. Energy Output

was measured as the sum of :

- **Total Biomass produced by all the crops = for every crop:** total ha cultivated * kg / ha dry matter produced * SEQ + kg / ha dry matter of secondary products (e.g.: straw) * SEQ
- **Waste** (sold or otherwise transferred out of the farm) = kg * SEQ
- **Vegetal byproducts** (sold or otherwise transferred out of the farm) **=** kg dry matter of byproducts * SEQ
- **Animal products, raw or processed** (sold or anyway transferred outside of the farm**) =** kg / ha dry matter * SEQ

d. Energy output / input ratio

Self evident

e. N Balance was calculated as

N Input - N Output

***Input** = Sum of the following:*

- **Organic fertilizers used** = kg * default values (kg N contained in 1 kg of fertilizer) OK

- **Mineral fertilizers used** = kg * SEQ * default values (kg N contained in 1 kg of fertilizer) - *not considered*
- **Biological nitrogen fixation =** crop * cultivated hectares * default values (kg N fixed by the crop every year)
- **Atmospheric nitrogen fixed** = 15 kg / ha * y

***Output** = Sum of the following:*

- **kg N in the sewage** (sold or otherwise transferred from the farm) kg * default values (kg N contained in 1 kg of sewage)
- **Plant products, raw or processed** (sold or otherwise transferred from the farm) **= for every crop:** total ha cultivated * kg / ha dry matter produced * default values (kg N contained in 1 kg of vegetal product, raw or processed, rejects included)
- **Animal products, raw or processed (**sold or anyway transferred outside of the farm) **=** kg dry matter produced * default values (kg N contained in 1 kg of animal product, raw or processed, rejects included)

N.B.: *default values* used are taken from the official table of food composition of INRAN (National Research Institute for Food and Nutrition) http://www.inran.it/servizi_cittadino/per_saperne_di_piu/tabelle_composizione_alimenti

f. P_2O_5 Balance was calculated as

P_2O_5 Input – P_2O_5 Output

Input* =** Sum of the following:***

- **Organic fertilizers used** = kg * default values (kg P_2O_5 contained in 1 kg of fertilizer)
- **Mineral fertilizers used** = kg * specific SEQ * default values (kg P_2O_5 contained in 1 kg of fertilizer)

***Output** = Sum of the following:*

- **kg P_2O_5 content in the sewage** (sold or anyway transferred outside of the farm) kg * default values (kg P_2O_5 contained in 1 kg of sewage)
- **Plant products, raw or processed** (sold or anyway transferred outside of the farm) **= for every crop:** total ha cultivated ***** kg / ha dry matter produced * default values (kg P_2O_5 contained in 1 kg of vegetal product, raw or processed, rejects included)
- **Animal products, raw or processed** (sold or anyway transferred outside of the farm) **=** kg / ha dry matter produced * default values (kg P_2O_5 contained in 1 kg of animal product, raw or processed, rejects included)
- **N.B**.: *default values* used are taken from the official table of food composition of INRAN (National Research Institute for Food and Nutrition) http://www.inran.it/servizi_cittadino/per_saperne_di_piu/tabelle_composizione_alimenti

g. Work units per hectare

was measured as annual work = h / ha * y

Results

The most significant aspect in the comparison of the data are the cropping classes, so we classified the results according to this criterion.

Table 2. Average values for the ecological indicators in each of the four cropping systems

Indicators	Hedges and Rows	Energy Input	Energy Output	Energy output /input ratio	N balance	P_2O_5 balance	Work units per hectare
Cropping classes	m/ha	GJ/ha	GJ/ha		kg/ha	kg/ha	h/ha
Fruit crops (n = 16)	75,86 (*)	12,46	56,77	5,39	99,07	46,46	690,26
Herbaceous crops (n = 48)		13,28	164,64	14,93	134,93	-2,17	276,97
Horticultural crops (n = 6)		32,88	65,39	3,35	15,75	-23,25	65,56
Mixed crops (§) **(n = 11)**		12,54	106,79	10,18	82,97	2,61	460,73

(*) the data was available in only 39 farms (out of 81) and, in this case, the difference between cropping systems is not significant

(§) at least 20% of fruit or herbaceous crops

n = number of farms in each group (out of the 81)

Comments to the results

The survey has shown Research has shown that the indicators used allow to discriminate between different farms on the basis of the productive orientation (cropping classes).

The results of calculations show that it is possible to distinguish between the management of the farms.

No outliers were found and the values of the indicators found do not differ significantly from the average. The differences between the various results are all explicable on the basis of cropping systems, groups of acreage and different land types to which the different farms belong.

All the results of the survey were published in Bocchi S., Bechini L., Spigarolo R. "Indicatori agroecologici per l'agricoltura biologica" - Research handbook of Regione Lombardia n. 97, march 2009.

A tentative of comparison between organic and conventional farms

At the moment, it is not possible to drive a significant comparison between organic and conventional farms: a similar research "Application of Agro-Ecological and Economic Indicators in Northern Italy" conducted by DiProVe on conventional farms of the "Sud Milano Agricultural Park" was carried out on a different basis of data, mainly at crop level.

Anyway, the table below show three indicators (Energy input, Energy output and Energy O/I ratio) calculated at crop level for the main herbaceous crops, with the same formulas of the India survey.

The data show that the cultivation of herbaceous crops in organic farms have on average a lower consumption of energy and a better Energy O/I ratio than conventional farms.

Table 3. Average values for the ecological indicators in conventional farms

Crops	Corn	Rice	Wheat	Barley	Permanent meadows	Soybean	INDIA Herbac. crops
Indicators							
Energy Input (GJ/ha)	**27,3**	**22,7**	**16,4**	**12,0**	**13,1**	**11,6**	**13,28**
Energy Output (GJ/ha)	**220,3**	**138,2**	**156,0**	**164,3**	**139,3**	**139,3**	**164,64**
Energy O/I ratio	**8,5**	**6,2**	**10,1**	**14,5**	**10,6**	**10,6**	**14,93**

Perspectives

Now the research group is testing a website in which all farmers can input their data about the consumption of materials, fertilizers, fuel and so on (the same parameters of the survey).

The software calculate their indicators and compare them with the averages found in the survey. So the farmers can very easily compare their management system with simple parameters (the indicators), and try, e.g., to reduce their energy inputs and/or to improve the N balance. The website system memorize their data, so, 1 year later, submitting the new data after the change, they can evaluate their success. The website will be ready in march 2010.

The survey will be implemented with another step. In the second part of the survey, that will be carried out next year, also the livestock indicators will be considered and a comparison with conventional and/or sustainable farms will be developed.

Furthermore, we will try to find some parameters in order to realize a significant comparison between conventional and/or sustainable farms.

The preliminary data from a recent survey carried out by the IT group of iPOPY (a comparative analysis of one hundred municipal call for tenders for school meal services) shows that in the call of tenders for school canteens in Italy one of the most frequent requirement is to ask products coming from short supply chain, highlighting them as “zero km”. This request, however, is ambiguous and not allowed by European rules on transparency in tendering.

For this reason, in a recent conference held in Bologna, Italy, in September 2009 about the quality in school canteens, the IT group of iPOPY proposed to introduce the calculation of the footprint as an objective requirement to assess the ecological impact of the cropping systems and of the supply chain instead of using the zero km requirement.

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